Structural analysis, design and detailing using standard CAD software and standard building information model

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Summary

This paper describes the concept of a german commercial software package developed for the needs of structural engineers. Using a standard CAD software as user interface for all geometrical data and to save all important input data, there is a natural link to upcoming building information models.

1 Introduction

In 1993 the author presented a paper (Fink 1993) at the V-ICCCBE in Los Angeles, covering almost the same topic. It was shown, that modelling structures with Finite Elements was possible within AutoCAD. In these days, data handling was done by attaching data to native AutoCAD elements. Using the "AutoCAD Development System ADS" it was possible to develop a basic user interface and mainly the export/import functionality to SOFiSTiK's database for Finite Elements "CDB". The level of abstraction was on the stage of Finite Elements and not building components. AutoCAD naturally did not know, what to do, in case of standard commands like COPY, MOVE or ERASE beeing applied on the elements.

2 Structural Elements

During the european Research project INSIDE methods have been developed and implemented, which allow modelling arbitrary structures with a combination of three object types: Structural area, structural line and structural point. A structural point may be the end of a structural line without any other properties as well as a column support or any other constraint within an area. A structural line may be part of the boundary of an area, define support condition or may represent a beam, cable or truss. This is done by simply defining a cross section number.

For analysis purpose these structural elements are exported into SOFiSTiK's database CDB. Finite Elements for the analysis are generated in the background (Rank et. al. 2000). One of the main benefits is, that modifications of the structure are easily possible with basic CAD-commands like MOVE and STRETCH.

3 Object ARX

Object ARX (AutoDesk 2000), an API available since AutoCAD 14, allows third party developers to implement their own objects, which behave like native CAD objects like lines, arcs and circles when treated with standard CAD commands. Graphical and nongraphical objects can be stored within the drawing file DWG.

This technique is widely used by SOFiSTiK to implement structural elements, load representations, Finite Elements as well as reinforcement bar objects for the process of detailing.

4 SOFiSTiK, SOFiPLUS and SOFiCAD

4.1 SOFiSTiK

Starting in the early 80ties, one of the principles of SOFiSTiK always was, to have several smaller programs, which share information via a central database, called CDB. About 50 different modules are available for tasks like linear and nonlinear analysis, various design tasks for different materials, vizualisation, printout and so on. This includes special programs for dynamics, halfspace analysis, seepage, thermal analysis, formfinding and several more.

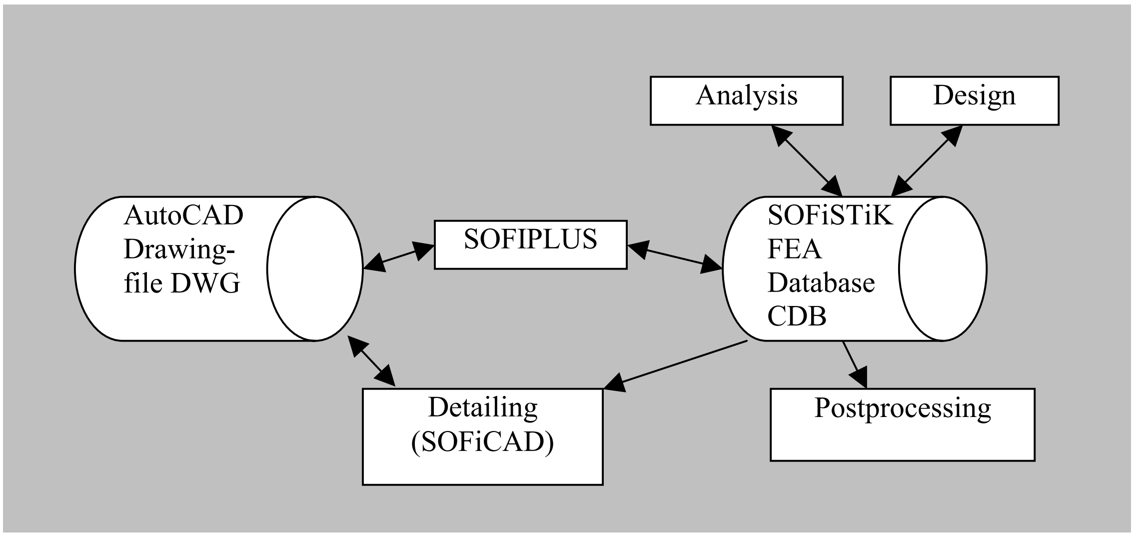

Fig. 1: General design of the program chain

4.2 SOFIPLUS

SOFiPLUS is the realization of the idea, to do all preprocessing within a standard CAD program (AutoCAD). It is very likely, that design data is already available in AutoCAD or can be easily converted into it. Many engineers in the world know how to operate this program. All relevant input data as well as all loading information can be created and saved within the drawing file. This can produce a permanent relation to the building model. SOFIPLUS extends AutoCAD with the relevant structural object definitions as well as commands to create and modify them. By exporting this data into CDB, most analysis and design tasks can be done from within AutoCAD.

4.3 Data Handling

Rather soon, the database has become a multitasking database allowing simultaneous access by different processes. This behaviour is not very compatible with a single user CAD environment. Thus the next step was either to have access from all other programs to the drawing database or to define the analysis database as master. We have chosen the second approach and solved some important issues:

Which data is to be saved where ? Clearly, the large amount of numerical results of a FE-analysis should not be saved into the drawing, while important material data should be saved in the drawing as well. The general design principle was to save all essential data as backup in the drawing as a binary copy of the real database within the named object dictionary (NOD) of AutoCAD.

What does it mean to “save” data (in the drawing or the database)? There is data like material or other properties which may be changed in an atomic way without impact on other tasks, and there is data (nodes and elements) which should not be replaced in such a way but as a complete set. This implies that the user may have a copy of some data to work on. Only if he decides to apply his changes, the database has to check, if the data has been locked correctly or if an other process has changed the data in the meantime.

4.4 SOFiCAD

SOFiCAD is SOFiSTiK’s package for detailing. Specialized for reinforced concrete structures a special object model representing the reinforcement bar data on the drawing was developed. Specialized commands use the design results from the CDB-file to create detailing drawings for special building components like slabs and walls

5 Sample

Sample is an abutment of a railway bridge. The model made with Architectural Desktop (Fig. 2). contains 11 columns representing the piles, one slab and 5 walls. This geometry can be converted into structural elements. Very helpful in this case is, that with SOFiSTiK, the definition plane for shell elements does not have to be the center plane. Having the elements hanging “below” or “above” the definition plane makes it a lot easier to model the structure (Fig. 3).

Fig. 4 shows the detailed reinforcement for the ground slab, automatically created using the information of the building model as well as the design data from the analysis database.

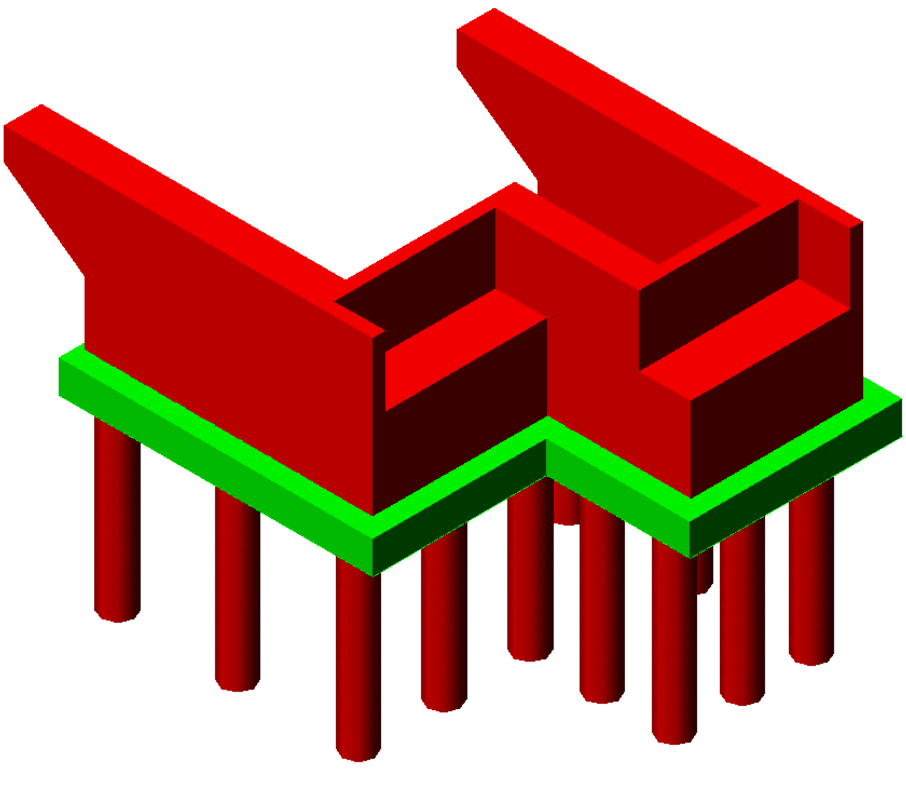

Fig. 2: Model of an abutment in Architectural Desktop ADT

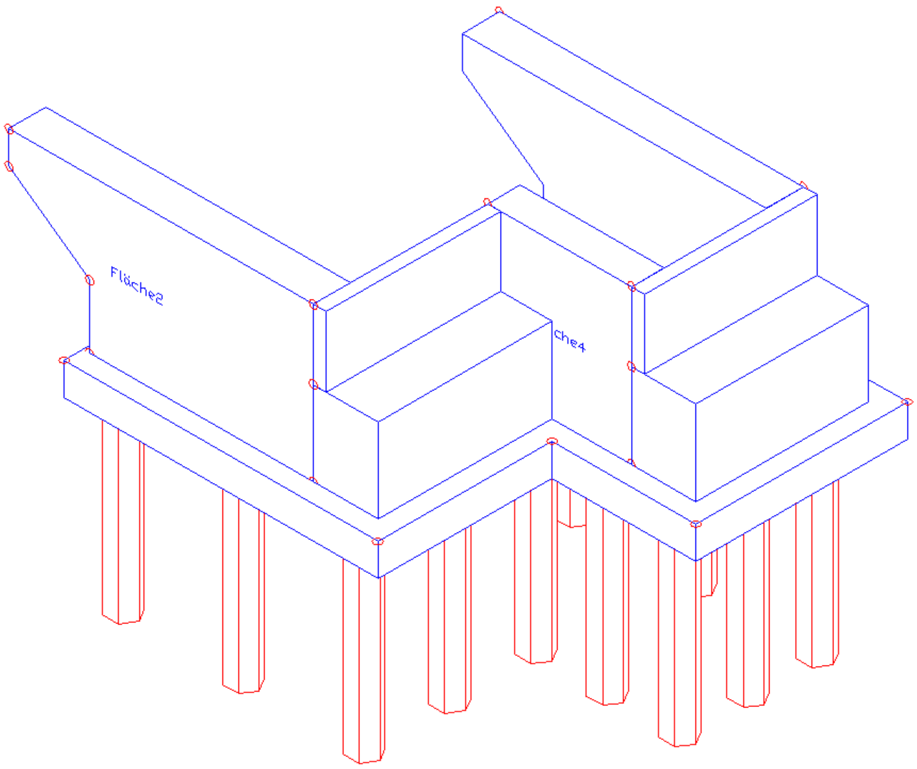

Fig. 3: Structural model with definition points

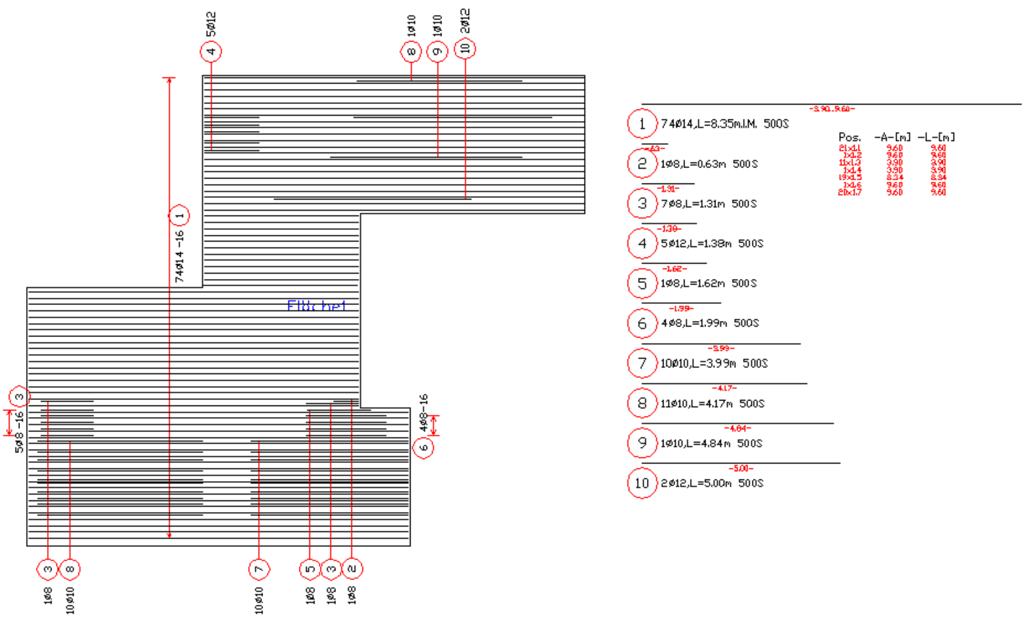

Fig. 4 Reinforcement of the ground slab (upper layer, one direction only)

6 Endnotes

During the last years a working group of the german chapter of the IAI (Industry Alliance for Operability) standarized the structural model used as part of the specification IFC 2.x (Fink 2002). After implementation of the model it is expected, that the whole work flow will be improved further.

7 References

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